HYDROGEN SULFIDE ODOR CONTROL IN WASTEWATER COLLECTION SYSTEMS

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INTRODUCTION

For some time, the Town of Bedford, Massachusetts had been receiving complaints about odors coming from the sewer system in neighborhoods downstream of its Middlesex Turnpike Pumping Station. The odor complaints initiated an investigation of the sanitary collection system upstream of the neighborhoods. The layout of the collection system indicated two potential problem areas. The Middlesex Turnpike Pumping Station pumped sewage through a 2,500-foot force main, which eventually fed a 21-inch reinforced concrete pipe with a very shallow slope. Both of these areas had the potential to produce hydrogen sulfide (H_2S); thus the Town decided to undertake an H_2S monitoring program to further assess the problem.

PROJECT BACKGROUND

The Middlesex Turnpike Pumping Station collects domestic wastewater from 5,300 linear feet of gravity sewer. A substantial portion of the station's flow is generated during normal work hours (8am to 5pm, Monday through Friday). The service area of the station is populated with numerous office parks and one major hotel/conference center with substantial dining facilities. Most of the office parks also have on-site cafeterias for their staff, which contribute to the organic load. Biochemical oxygen demand (BOD) in this area is strong, ranging from 300 to 320 milligrams per liter (mg/l). Soluble BOD ranges from 71 to 150 mg/l.

As previously mentioned, the Middlesex Turnpike Pumping Station has a 2,500-foot, 8-inch force main that carries flow to a gravity sewer on Crosby Drive, and has detention times as long as 90 minutes. The gravity sewer on Crosby Drive feeds a 21-inch reinforced concrete pipe with a minimal slope on Route 62. The slow moving flow in this pipe creates another area for sulfide production. At the intersection of Route 62 and Hemlock Lane, there is a manhole with a 4-foot hydraulic drop, which also allows for the release of H_2S.

ATMOSPHERIC HYDROGEN SULFIDE MONITORING

The Town used the Massachusetts Water Resources Authority (MWRA) Community Assistance Program to install atmospheric H_2S meters in three locations downstream of the Middlesex Turnpike Pumping Station suspected of having the highest H_2S concentrations. The force main discharge manhole on Crosby Drive, the manhole at the intersection of Crosby Drive and Route 62, and the drop manhole at

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the intersection of Route 62 and Hemlock Lane were chosen as the locations for Meters 1, 2 and 3, respectively. Each of these locations, shown in Figure 1, had turbulent flow conditions conducive to the release of sulfides to the atmosphere. Peak atmospheric H_2S readings recorded at these sites during the monitoring program were 81 parts per million (ppm), 36 ppm, and 80 ppm, respectively. H_2S levels of these magnitudes cause odor problems, pose health risks to collection system operators, and may deteriorate the structural integrity of sewer infrastructure.

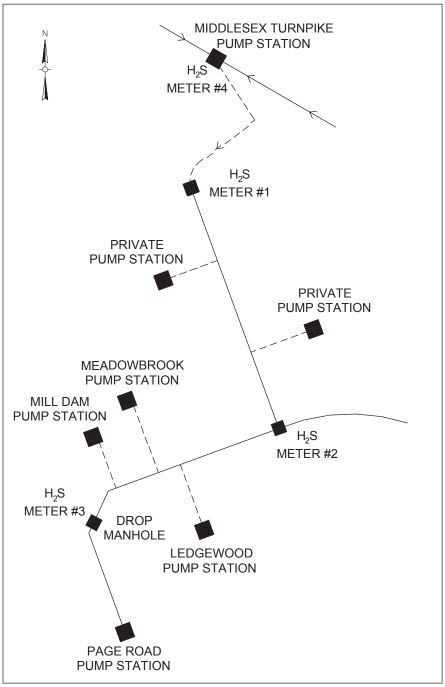

Figure 1. LOCATIONS OF METERS INSTALLED FOR H_2S MONITORING PROGRAM

The results of the monitoring program showed that corrective measures needed to be taken to eliminate residential complaints and protect the sewer system and worker health and safety.

As a first attempt to resolve the problem, the Town used 25 percent sodium hydroxide to "shock the force main" to arrest H_2S production. This technique successfully decreased the atmospheric H_2S concentrations at Meter 1 by killing sulfate-reducing bacteria in the force main; however, the effect of the sodium hydroxide was short-lived, and concentrations quickly returned to previous levels, as Figure 2 shows. This

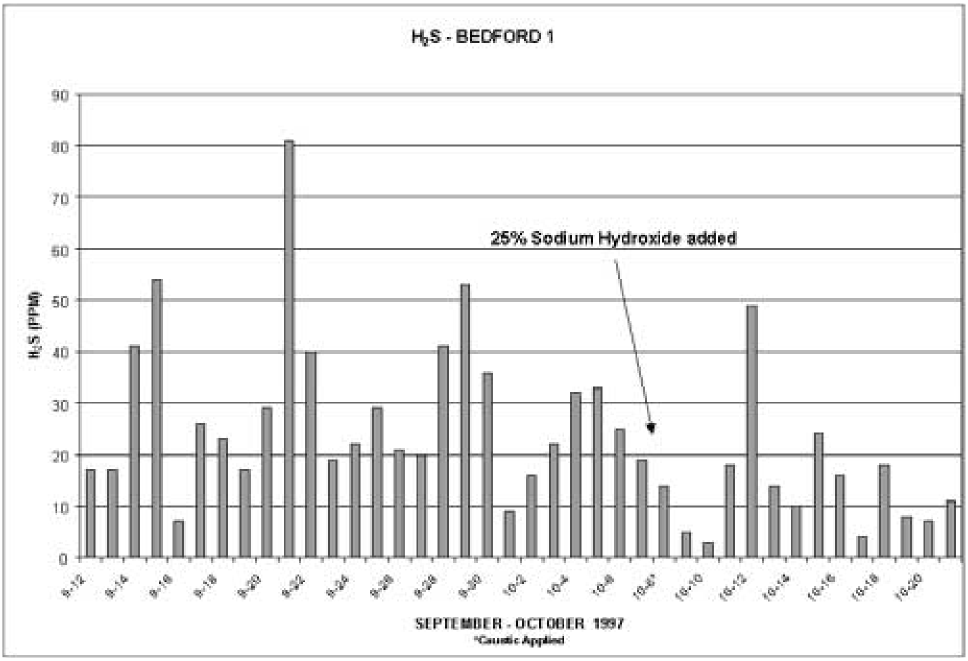

Figure 2. SODIUM HYDROXIDE DOSING

collection system would require a longer lasting, more-effective method of controlling sulfides.

H_2S *PRODUCTION*

To effectively treat H_2S in wastewater collection systems, one must understand the mechanisms of its production. In collection systems, H_2S is produced when bacteria consume sulfate oxygen for organic processes. Sulfate-reducing bacteria grow in a "slime layer" that coats the sewer's wetted perimeter. These bacteria use oxygen in the most readily available form: first, from elemental oxygen; then, nitrate oxygen; then, sulfate oxygen. As nitrate is usually not available in wastewater, bacteria will consume sulfate oxygen after depleting elemental oxygen, leaving bi-sulfide ions to combine with hydrogen to form aqueous H_2S. Figure 3 illustrates these reactions. At pH 7, the bi-sulfide ion and aqueous H_2S, in solution, are equally proportionate. pH, Henry's Law, and the turbulence of the waste stream govern the rate at which aqueous H_2S is converted to atmospheric H_2S. A lower pH produces more aqueous H_2S and increases the rate of H_2S transfer to the gas phase. Turbulent wastewater also facilitates the release of H_2S to the atmosphere.

As H_2S is released into the sewer atmosphere, it combines with water on the crown of the pipe to form sulfuric acid (H_2SO_4). Figure 3 also shows this reaction. Because H_2SO_4 corrodes the sewer infrastructure, it is necessary to stop H_2S production in the collection system.

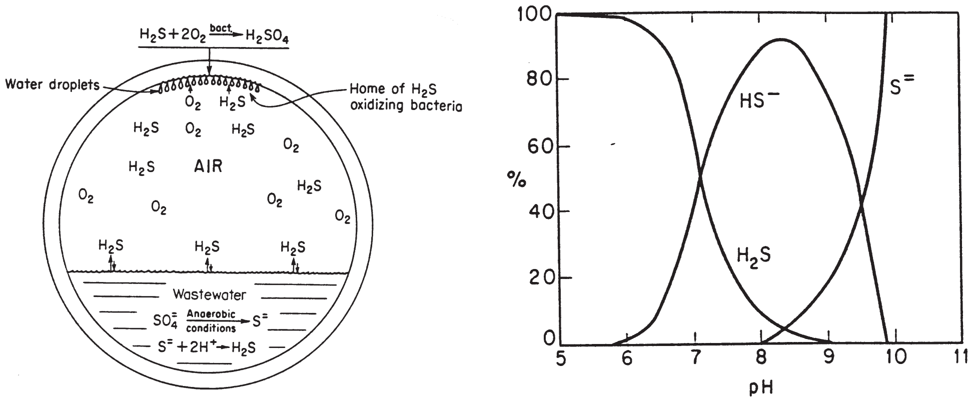

Figure 3. HYDROGEN SULFIDE CHEMISTRY

PROJECT APPROACH

Manipulating the environment that bacteria use to support their growth is one way to control sulfide odors. Our project approach, which involved bench-scale tests followed by a pilot study, sought to alter the environment conducive to H_2S production by introducing nitrate to the sewer system. Bacteria need oxygen to metabolize organic matter. As was previously discussed, after consuming elemental oxygen, bacteria will first use available nitrate, then sulfate. During our investigation, we found that the dissolved oxygen concentration in the Middlesex Station wet well averaged 4.4 mg/l. This aerobic wastewater was pumped through the force main each time the pumping station was activated. The dissolved oxygen level in the wastewater decreased as the flow was pumped through the force main. After the elemental oxygen was consumed, the bacteria began to use alternate sources of oxygen. Before the pilot program was implemented, that source of oxygen was in the form of sulfate. Theoretically, the introduction of nitrate into the collection system should provide an oxygen source for the bacteria's use that will stop the reduction of sulfate, which is the first step in sulfide production.

We contacted an agricultural supply house and found that there were several nitrate-based chemicals that could be purchased. Table 1 shows a list of nitrate chemicals commonly available. Calcium nitrate was selected because of its low price and ease of handling.

Table 1. NITRATE PRODUCTS

Product	Cost per Ton	Cost per Pound
Nitrate of Soda	$366	$0.183
Potassium Nitrate	$646	$0.323
Calcium Nitrate	$312	$0.156

Bench Tests

We conducted a series of bench tests to evaluate the nitrate concentrations of various mixtures of calcium nitrate and water. By adjusting the number of pounds of dry chemical added to the water in the chemical feed tank, we were able to increase or decrease the nitrate level to a desired concentration. Table 2 presents the cost of calcium nitrate at various concentrations.

Table 2. CALCIUM NITRATE BENCH TESTS

$CaNO_3$ (grams/200ml))	Lab Concentration Nitrate (mg/l)	Pounds of $CaNO_3$ (needed for 1 gallon)	Cost of $CaNO_3$ ($/lb)	Cost of $CaNO_3$ ($/gallon)
0	-	-	$0.15	-
10	34,000	0.417	$0.15	$0.06
20	60,000	0.834	$0.15	$0.13
50	140,000	2.086	$0.15	$0.31
297*	440,000	12.391	$0.15	$1.86

* Grams of calcium nitrate at saturation

Pilot Program

Our pilot study included the following basic elements:

- A chemical pump (LMI) to regulate the gallons of chemical discharged each day.
- A 376-gallon plastic chemical feed tank.
- A $^1/_4$-hp mixer to dissolve the dry product.
- A metal shed to house the equipment.

The Town of Bedford Department of Public Works staff performed all the work to wire the station for power and provide water.

To monitor the pilot program's results, we installed four atmospheric H_2S meters at the following locations: the Middlesex Turnpike Pumping Station; the force main discharge manhole on Crosby Drive; the manhole at the intersection of Crosby Drive and Route 62; and the drop manhole at the intersection of Route 62 and Hemlock Lane. Throughout the pilot study, these monitors took readings in five-minute increments. Grab samples were also collected from the monitoring sites to supplement the atmospheric data. Two grab samples were taken at each of the monitoring locations to establish baseline data, and additional samples were taken each time the calcium nitrate concentration or feed rate was adjusted.

Two factors controlled the amount of nitrate oxygen being introduced to the wet well: the concentration of the calcium nitrate solution and feed rate of the pump. The chemical concentration varied between 140,000 and 350,000 mg/l of nitrate. A concentration of 140,000 mg/l of nitrate was found to be the easiest to administer and the most cost-effective for controlling odors. The chemical feed rate varied from 35 to 67 gallons per day (gpd). The best results were obtained when the feed rate was between 45 and 60 gpd. According to Table 2, about 622 pounds of calcium nitrate dissolved in 298 gallons of water was required to discharge 45 gpd of solution with a nitrate concentration of 140,000 mg/l. This chemical solution cost about $93 to make and had a duration of 6.5 days.

RESULTS

Two points during the pilot program clearly illustrated the effectiveness of the treatment system. The first occurred at the beginning of the program when the chemical feed system was turned on. During the 11 days before the system was started up, atmospheric H_2S levels were recorded as high as 68 ppm at the force main discharge manhole. On May 11, 1998, the pilot tank was turned on and the atmospheric level decreased to zero ppm over the next 3 days, as Figure 4 shows.

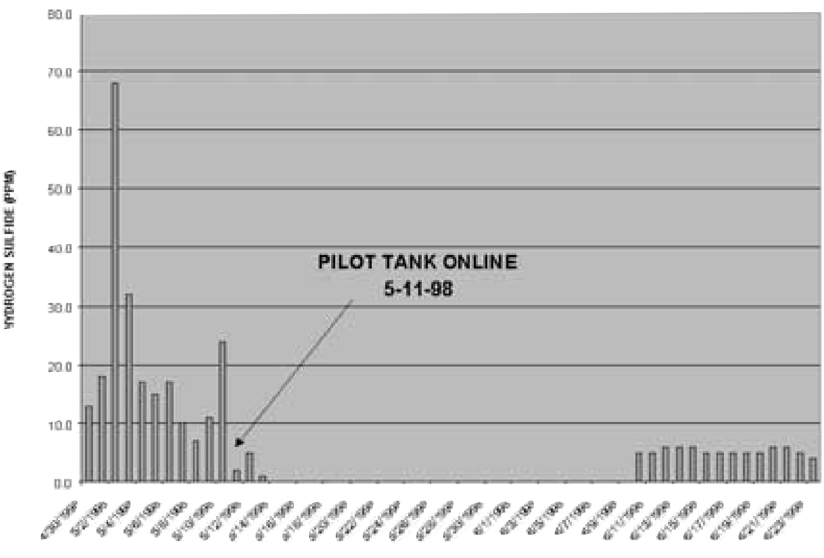

Figure 4. CHEMICAL FEED START

The H_2S monitors recorded levels less than 6 ppm through June 23, when they were removed. (Monitors were also removed from June 3 to June 9). The second illustration of the program's effectiveness occurred on August 14. The atmospheric monitors were reinstalled on August 11, but the pilot tank was not restarted until August 14. Figure 5 shows that the atmospheric H_2S readings prior to pilot tank operation were as high as 34 ppm at the force main discharge manhole, and then decreased to zero three days after the chemical feed tank was restarted.

Calcium nitrate was less effective in reducing atmospheric H_2S concentrations further downstream at the intersection of Crosby Drive and Route 62 and at the Hemlock Lane drop manhole; however, each location experienced a noticeable decrease in H_2S concentrations. Peak readings decreased from 36 to 25 ppm at Crosby Drive and Route 62, and from 80 to 32 ppm at Hemlock Lane. An additional chemical feed

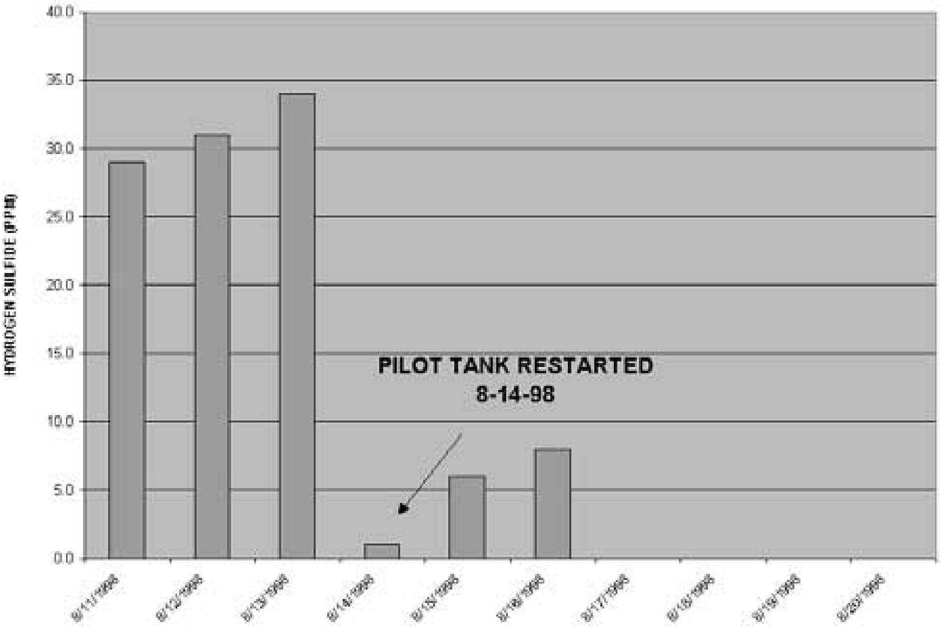

Figure 5. CHEMICAL FEED RESTART

station could be installed at Crosby Drive and Route 62 to control the release of sulfides in this section of the collection system.

CONCLUSIONS

There are many approaches to deal with H_2S odors. One broad approach is to change the environment within which the bacteria live. We chose this alternative by introducing nitrate, which bacteria will seek out as an oxygen source before using sulfate, breaking the sulfide production chain. Depending on the configuration of individual collection systems, multiple dosing stations may be required to accomplish this task.

Nitrate addition provides an easy, cost-effective way to control H_2S odors in collection systems. Bedford's pilot program cost the Town under $1,000 to implement and effectively eliminated odor complaints, arrested the corrosion of the sewer infrastructure, and provided a safer work environment for collection system operators.

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